January 11, 1872.

GEORGE BIDDELL AIRY, C.B., President, in the Chair.

The following communications were read :—

I. "Experiments made to determine Surface-conductivity for Heat in Absolute Measure." By Donald M'Farlane. Communicated by Sir William Thomson, F.R.S. Received August 8, 1871.

The experiments described in this paper were made in the Physical Laboratory of the University of Glasgow, under the direction of Sir William Thomson, during the summer of 1871. A set of similar experiments were made in 1865; but being merely preliminary, carried on by different individuals, and embracing only a limited range of temperatures, it is thought unnecessary to allude further to them here*.

A copper ball, 2 centimetres radius, having a thermo-electric junction at its centre, was suspended in the interior of a double-walled tin-plate vessel which had the space between the double sides filled with water at the atmospheric temperature, and the interior coated with lamp-black. The other junction was in metallic contact with the outside of the vessel, and the circuit was completed through the coil of a mirror galvanometer. One junction was thus kept at a nearly constant temperature of about 14° Cent., while the other had the gradually diminishing temperature of the ball.

Having adjusted the galvanometer to the degree of sensitiveness desired, the copper ball was heated in the flame of a spirit-lamp till its temperature was considerably above that required to throw the spot of light off the scale; it was then put into position in the interior of the tin-plate vessel, and as soon as the spot of light came within range, the deflections from the zero position were noted at intervals of one minute exactly till the change of deflection was reduced to about two scale-divisions per minute.

Two series of experiments were made in this way, each consisting of several sets of readings. In the first the ball had a bright surface, and in the second it was coated with a thin covering of soot from the flame of a lamp, and in both the air was kept moist by a saucer containing a quantity of water placed in the interior of the tin-plate vessel.

As the range of differences of temperatures of the junctions extended over 50° Cent., the change in the difference of thermo-electric qualities of the copper and iron wires forming the junctions was very considerable,

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* These experiments consisted of two series, one with the air moist by a little water placed in the interior of the vessel, the other having the air dried by substituting sulphuric acid for the water in the first; and the results in the two cases were so nearly alike, that any effect due to the moisture or dryness of the air could not be distinguished from errors of observation. From this circumstance, as well as the limited range of temperatures, these results are not given here.

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and it was necessary to make a careful thermometric comparison of the temperatures of the junctions and galvanometer deflections. For this purpose the junctions were tied to the bulbs of two previously compared thermometers, having their stems divided to tenths of a degree Cent.; these were then placed in two vessels of water, one at the temperature of the air, and the other heated by small additions of hot water, and kept well stirred; simultaneous readings of the thermometers and galvanometer deflections were then taken at various points of the scale*, from which the formula

$$y=0^\circ{\cdot}0924+0^\circ{\cdot}0000227x$$

was obtained, where y is the value of a scale-division in terms of a degree Centigrade, and x the galvanometer deflection; and the difference of temperature of the junctions is therefore

$$xy=0^\circ{\cdot}0924x+0^\circ{\cdot}0000227x^2,$$

from which the numbers in col. II. of the following Tables were calculated.

The method adopted in reducing the observations was this:—Each single set of readings was arranged in a vertical column, and the whole series placed side by side with corresponding numbers in the same horizontal line; the means of the horizontal lines were formed into a similar column, and divided into groups, each consisting of four consecutive numbers, and the means of these groups form the numbers in col. I. of the Tables.

Col. II. contains the differences of the temperatures of the junctions at intervals of four minutes, corresponding to the mean deflections in col. I.

Col. III. contains the common logarithms of the numbers in col. II.

Col. IV. contains the differences of the successive numbers in col. III. divided by 4.

Col. V. is formed from col. IV., by multiplying by the Napierian logarithm of 10, and is the rate at which the difference of temperature varies per minute.

Col. VI. shows the quantity of heat emitted from the ball in gramme-water units per square centimetre per second per degree of difference of temperatures, and is formed by multiplying the numbers in col. V. by ·009385†, a constant depending on the surface of the ball and its capacity for heat.

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* These readings were plotted, and the curve drawn through the points agreed very closely with a portion of a parabolic curve whose equation is

$$y=2{\cdot}4+10{\cdot}6x-{\cdot}019x^2,$$

y denoting the deflections of the galvanometer, and x the difference of temperature; y is a maximum when $x=\dfrac{10{\cdot}6}{{\cdot}038}=279^\circ$, and, the colder junction having been at 16° Cent., we get 295° as the neutral point of the specimens of copper and iron wires used—a very close agreement with former observations, considering the great distance of the neutral point from the temperature of the observations.

† The surface of the ball was 50·26 sq. centimetres, and its capacity for heat 28·31

The numbers found in cols. VI. and VII. were plotted on squared paper, and a mean curve drawn through the points; and, assuming the quantity of heat emitted to be represented by the formula $x=a+bt+ct^2$, where t is the difference of temperature, the coordinates of the curve were employed to determine a, b, and c; and col. VIII., calculated by the formula, is added to show the degree of approximation to which the results of the experiment are represented by it.

First Series.

Atmosphere moist. Copper Ball polished bright.
Means of nine sets of Observations.

I. Mean deflections of nine sets of observations.	II. Difference of temperature, D.	III. $\log_{10}$ D.	IV. $\frac{\log_{10} D' - \log_{10} D''}{4}$.	V. $\frac{\log_\epsilon D' - \log_\epsilon D''}{4}$, C.	VI. Heat emitted per second by observation.	VII. Mean difference of temperature, $\frac{1}{2}[D'-D'']$, (t).	VIII. Heat emitted per second, calculated by formula, (x).
627·19	66°·88	·82527	·01037	·02387	·000223	63°·83	·000230
576·28	60·79	·78380	·01045	·02406	·000226	58·00	·000227
528·82	55·21	·74200	·01055	·02429	·000227	52·65	·000226
484·50	50·10	·69981	·01041	·02396	·000225	47·81	·000224
444·14	45·51	·65815	·01033	·02378	·000223	43·45	·000222
407·15	41·38	·61681	·01028	·02366	·000222	39·51	·000220
373·37	37·64	·57570	·01015	·02337	·000219	35·96	·000217
342·26	34·28	·53509	·01020	·02348	·000220	32·75	·000215
313·64	31·21	·49429	·00992	·02284	·000214	29·85	·000213
287·89	28·48	·45459	·00982	·02261	·000212	27·25	·000210
264·42	26·02	·41529	·00943	·02171	·000204	24·94	·000208
243·58	23·85	·37756	·00962	·02215	·000208	22·84	·000205
223·96	21·83	·33907	·00945	·02175	·000204	20·92	·000202
206·15	20·01	·30127	·00915	·02106	·000198	19·20	·000200
190·20	18·39	·26467	·00905	·02083	·000195	17·62	·000198
175·57	16·92	·22845	·00909	·02093	·000196	16·24	·000196
161·99	15·56	·19207	·00901	·02074	·000195	14·94	·000194
149·51	14·32	·15603					

Formula for calculating column VIII.:—

$$x = \cdot000168 + \cdot00000198t - \cdot000000017t^2.$$

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gramme-water units. Let x denote the heat emitted per second, per sq. centimetre per degree of difference of temperature, and C the rate at which the difference of temperature varies per minute; then

$$\frac{x \times 60 \times 50\cdot26}{28\cdot31} = C,$$

and therefore

$$x = \cdot009385\ C.$$

Second Series.

Atmosphere moist. Copper Ball blackened.
Ten sets of Observations.

I. Mean deflections of ten sets of observations.	II. Difference of temperature, D.	III. $\log_{10}$ D.	IV. $\frac{\log_{10} D' - \log_{10} D''}{4}$.	V. $\frac{\log_\epsilon D' - \log_\epsilon D''}{4}$, C.	VI. Heat emitted per second by observation.	VII. Mean difference of temperature, $\frac{1}{2}[D' - D'']$, (t).	VIII. Heat emitted per second, calculated by formula, (x).
631·85	67°·44	·82893	·01511	·03478	·000326	63°·06	·000328
558·46	58·68	·76849	·01510	·03477	·000326	54·87	·000328
492·92	51·06	·70808	·01488	·03426	·000322	47·79	·000325
435·27	44·52	·64856	·01476	·03399	·000319	41·69	·000321
384·29	38·86	·58950	·01460	·03362	·000315	36·42	·000315
339·49	33·98	·53122	·01433	·03300	·000310	31·88	·000311
300·20	29·78	·47392	·01391	·03202	·000301	27·99	·000303
266·11	26·20	·41830	·01377	·03170	·000297	24·64	·000298
236·12	23·08	·36324	·01358	·03126	·000293	21·72	·000292
209·65	20·37	·30899	·01325	·03050	·000286	19·20	·000287
186·59	18·03	·25600	·01311	·03018	·000283	17·00	·000283
166·14	15·98	·20358	·01290	·02970	·000279	15·09	·000279
148·16	14·19	·15198	·01258	·02896	·000272	13·41	·000274
132·46	12·64	·10165	·01265	·02902	·000272	11·94	·000271
118·29	11·25	·05104	·01230	·02832	·000266	10·70	·000268
105·97	10·04	·00186	·01236	·02846	·000267	9·50	·000265
94·79	8·96	·95240	·01261	·02903	·000272	8·47	·000262
84·59	7·98	·90195					

Formula for calculating column VIII. :—

$$x = \cdot000238 + \cdot00000306t - \cdot000000026t^2.$$

The following Table gives the results calculated by the formula for every fifth degree within the limits of the experiments :—

Difference of temperature.	Heat emitted.		Ratio of emissive power of polished to that of blackened surface.
	Polished surface.	Blackened surface.	
5°	·000178	·000252	·707
10	·000186	·000266	·699
15	·000193	·000279	·692
20	·000201	·000289	·695
25	·000207	·000298	·694
30	·000212	·000306	·693
35	·000217	·000313	·693
40	·000220	·000319	·693
45	·000223	·000323	·690
50	·000225	·000326	·690
55	·000226	·000328	·690
60	·000226	·000328	·690